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GB 1331394
GB 1211463
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(71) Applicant
Wool Development International Limited,
Kinnaird House,
1 Pall Mall,
East London

(72) Inventors
Yves Joskin,
Jose Muller,
Joseph Grignet,
Jean Marie Gillis

(74) Agent
Reddie and Grose,
16 Theobalds Road,
London,
WC1X 8PL

(54) Detection of defects in fibrous arrays

(57) Defects in an array of textile fibres, such as wool tops, laps or webs, are detected by passing the array 13 past at least one transmitted light sensor 11 and one reflected light sensor 21, and detecting the presence or character of a defect from signals produced by the sensors corresponding to the same parts of the array. The fibrous array is preferably drafted, for example by aprons 26 and rollers 27 and 28 and passed successively past transmission sensor comprising detector 12 and light source 14 and reflection sensor 21 comprising sources 24, sensor 22 and diffuse reflector 25, the signals produced by the first sensor 11 being synchronised with those produced by the second sensor 21 in respect of the same portion of the array. The detectors may be linear arrays extending transverse to the fibre array. The signals are analysed electronically to detect the presence or size of a defect, and to discriminate by means of differences in reflectance or transmittance between defects of different character.

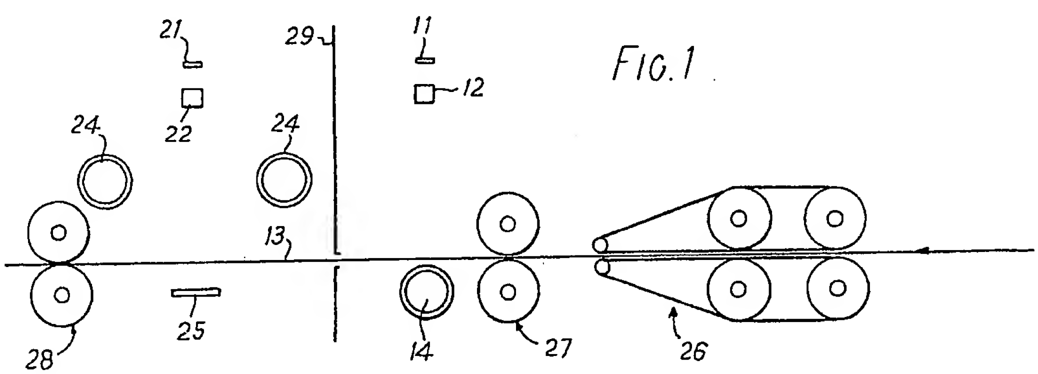

FIG. 1

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy

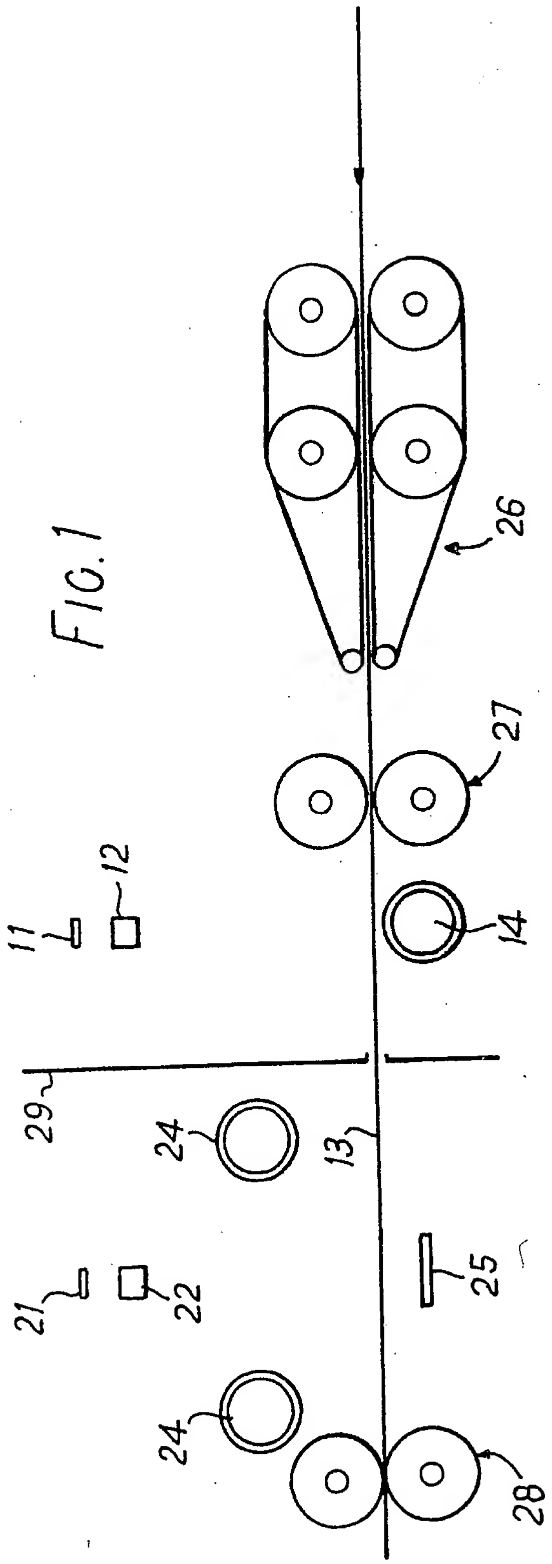


FIG. 1

FIG. 2

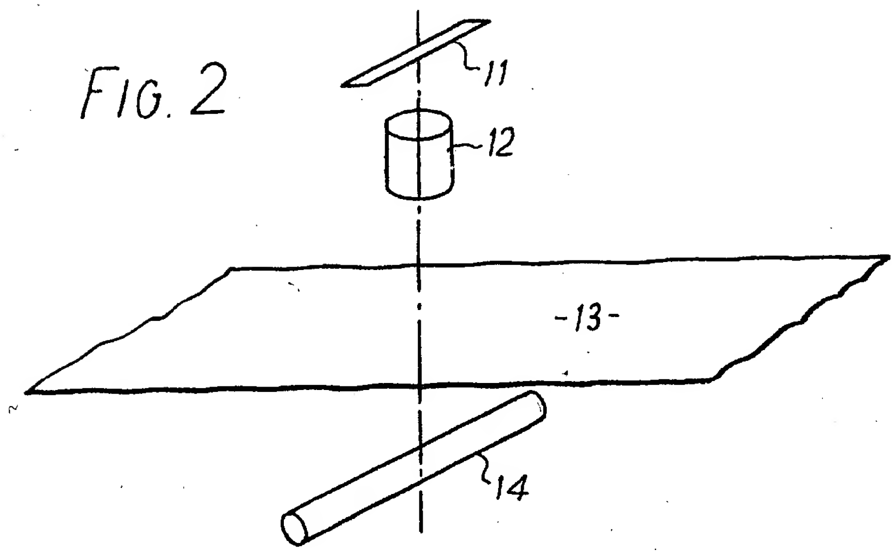
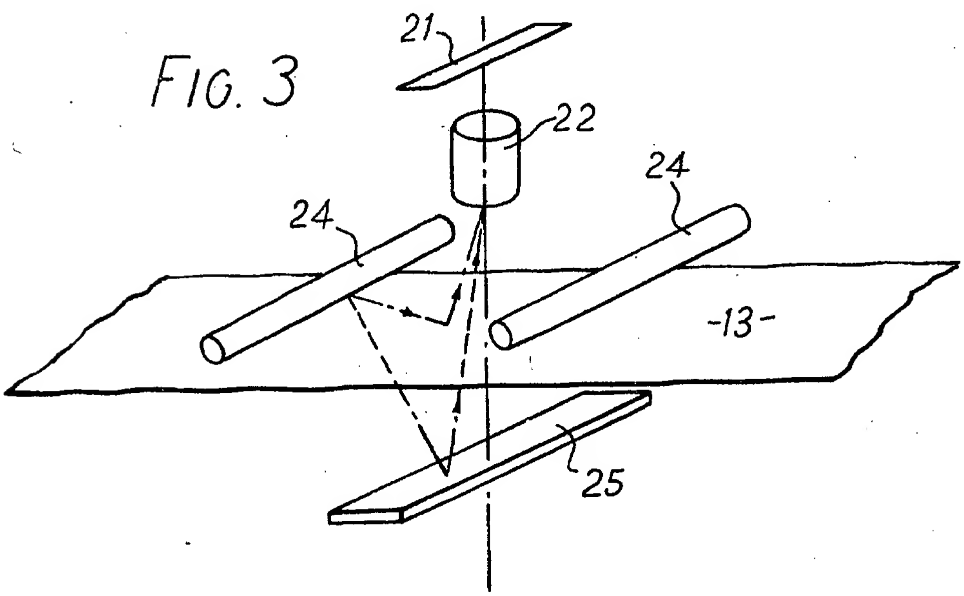


FIG. 3



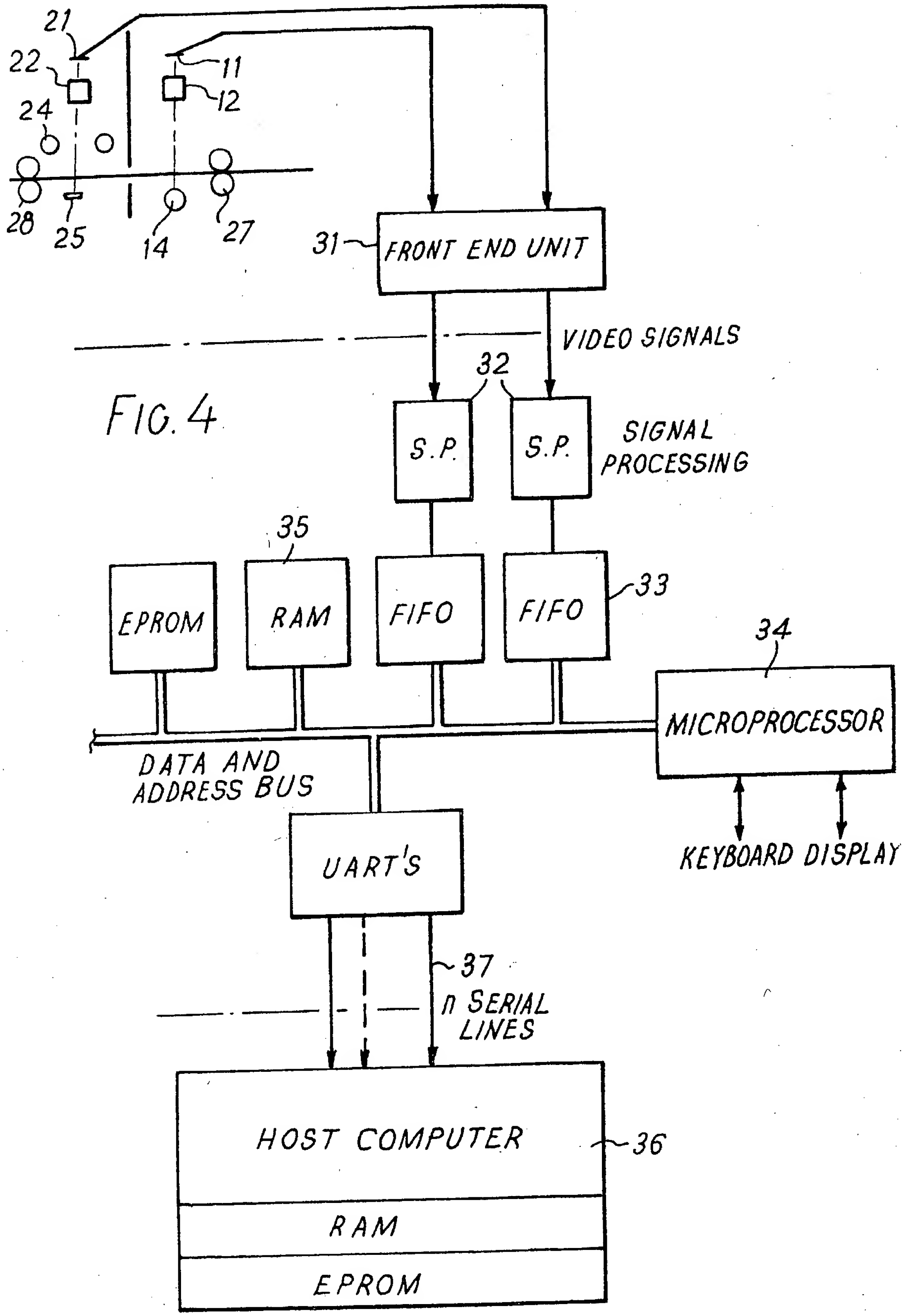

21
22
11
12
24
28
25
14
27
31
FRONT END UNIT
VIDEO SIGNALS
32
S.P.
S.P.
SIGNAL PROCESSING
35
EPROM
RAM
FIFO
FIFO
33
34
MICROPROCESSOR
DATA AND ADDRESS BUS
UART'S
KEYBOARD DISPLAY
37
n SERIAL LINES
HOST COMPUTER
36
RAM
EPROM

FIG. 4

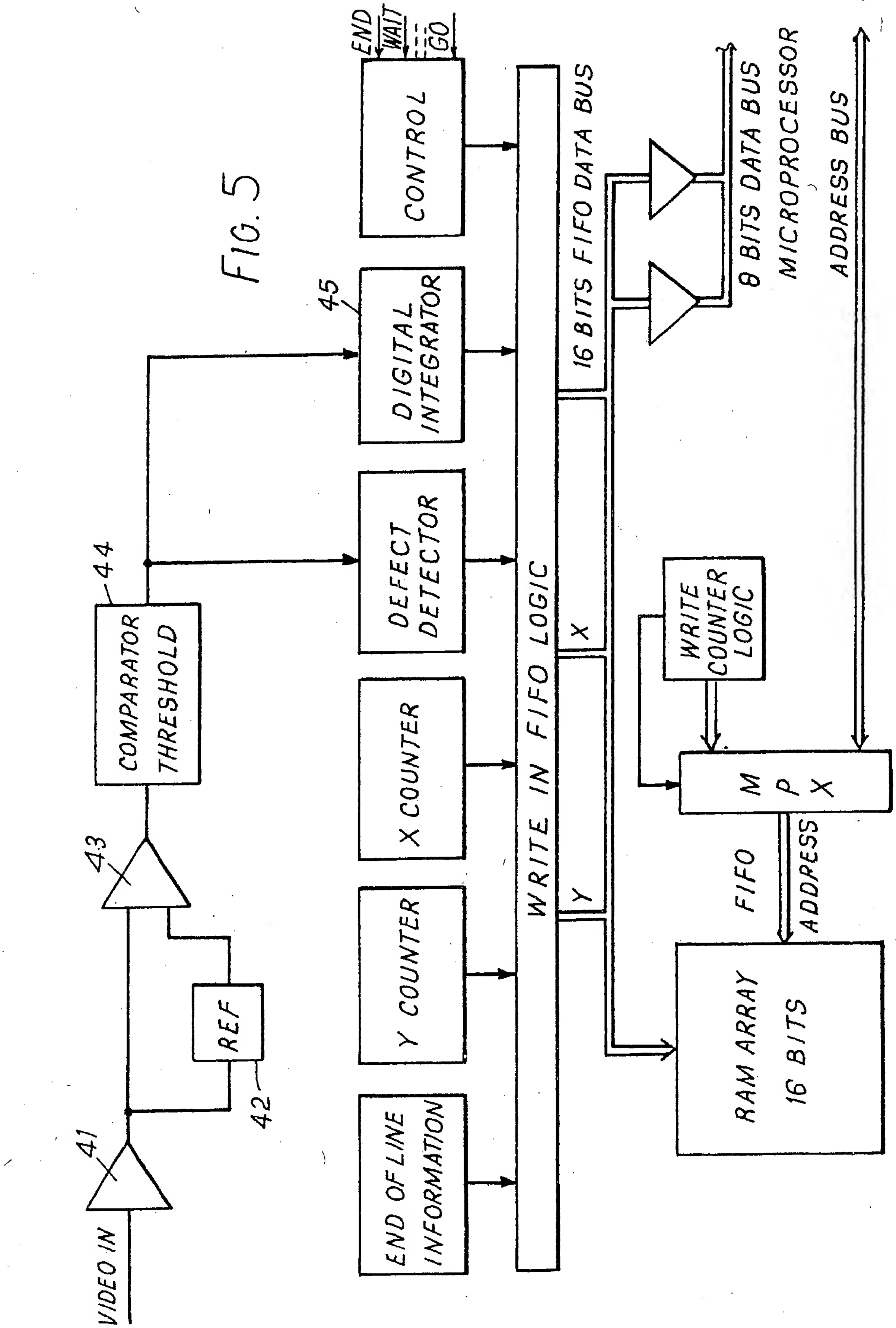

VIDEO IN
41
42
REF
43
44
COMPARATOR
THRESHOLD
45
DIGITAL
INTEGRATOR
DEFECT
DETECTOR
X COUNTER
Y COUNTER
END OF LINE
INFORMATION
CONTROL
END
WAIT
GO
WRITE IN FIFO LOGIC
16 BITS FIFO DATA BUS
X
Y
8 BITS DATA BUS
MICROPROCESSOR
ADDRESS BUS
WRITE
COUNTER
LOGIC
M P X
FIFO
ADDRESS
RAM ARRAY
16 BITS

FIG. 5

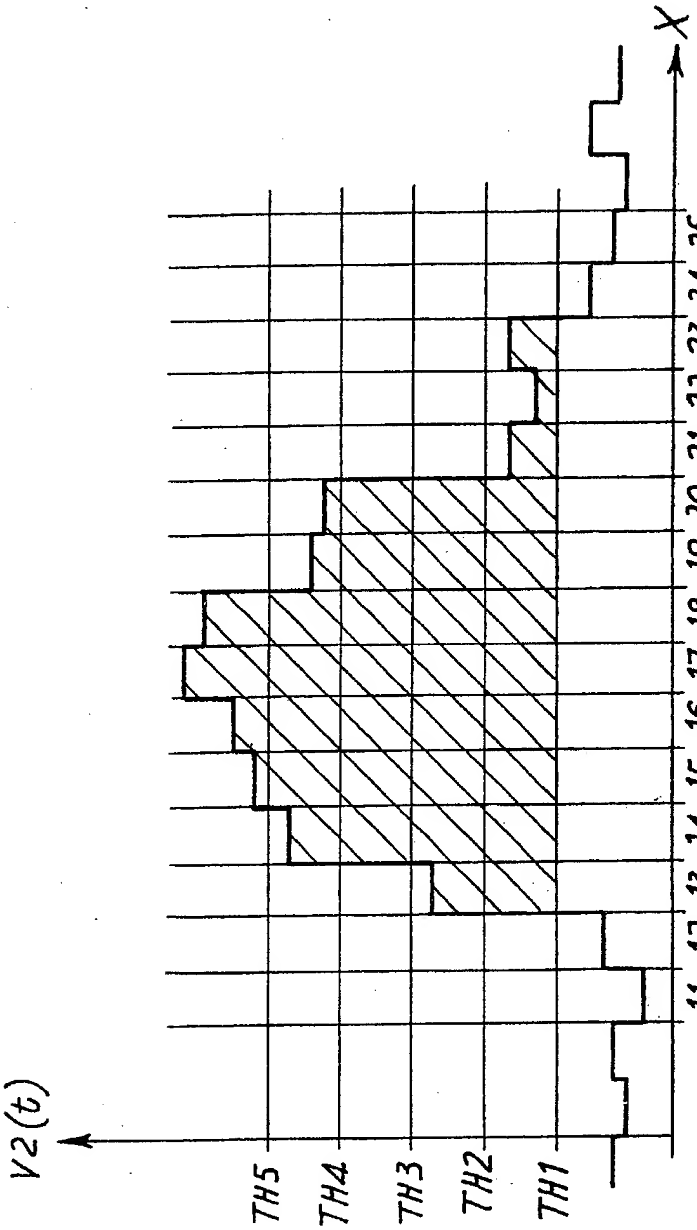


FIG.6

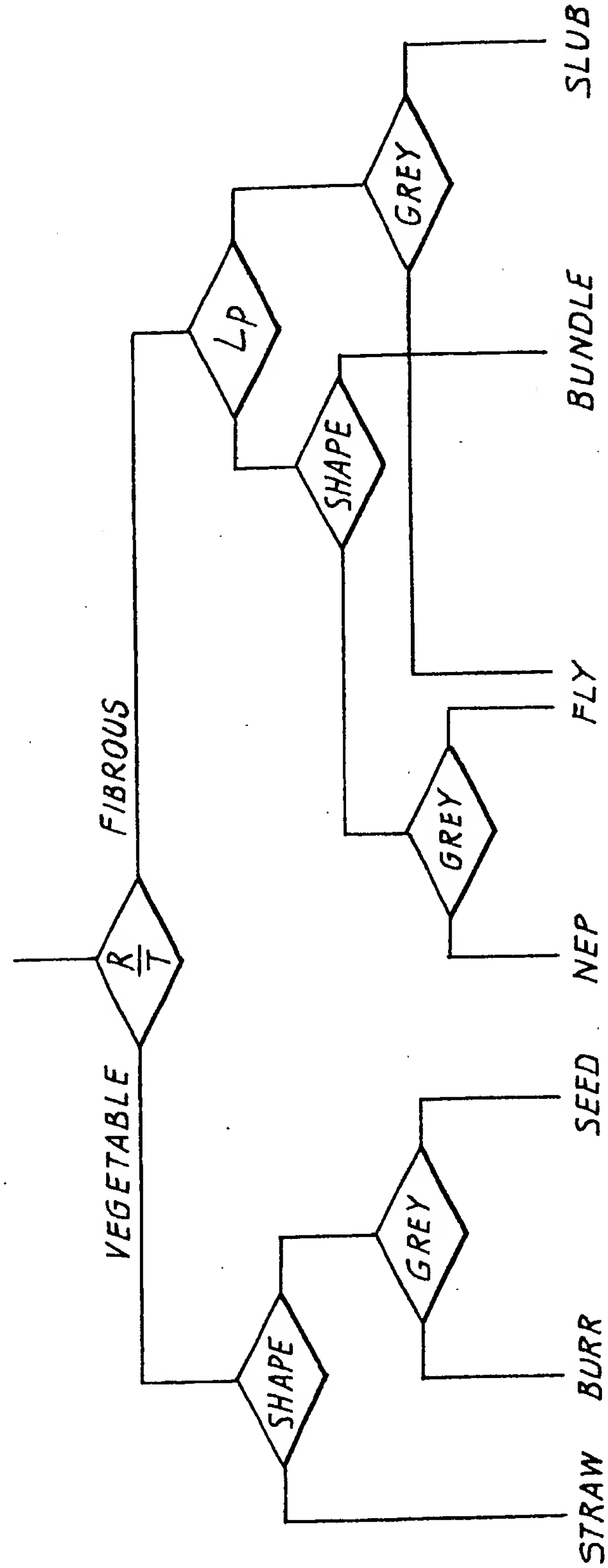

R/T
FIBROUS
VEGETABLE
Lp
GREY
SHAPE
GREY
SHAPE
GREY
SLUB
BUNDLE
FLY
FLY
NEP
SEED
BURR
STRAW

FIG.7

SPECIFICATION

Detection of defects in fibrous arrays

The present invention relates to the detection and characterization of defects in arrays of fibres, and more especially to methods and apparatus for detecting and measuring defects in tops and other laps or webs of textile fibres.

In accordance with this invention, light is directed onto an array of fibres as it passes one or more sensors, the transmitted or reflected light, or both, is detected, and from the resulting signals, the presence, size or character of any defect is determined.

The invention preferably employs two sensors, one arranged to detect primarily transmitted light and the other to detect primarily reflected light. The means employed to analyse the signals from the sensors, such as a computer, is then adapted to synchronise the signals produced by one sensor with those produced by the other sensor in respect of the same portion of the fibrous array. The operation of detecting reflected light preferably utilises two light sources, one on the same side of the array as the sensor and the other, which may conveniently be a diffusing reflector, on the opposite side. The sensor concerned then detects light from the first source reflected directly from the fibrous array, and light from the second source after transmission through the array. This is of particular value in discriminating between defects of different type or origin.

The purpose of the diffusing reflector is merely to form an illuminated background which makes the array of fibres disappear when observed in reflection from the side of the "reflection" sensor. Another possibility is to use for this background a ground glass or another opalescent material with an auxiliary light source which can be adjusted in intensity to ensure the disappearance against the background of the fibre array.

Each sensor is preferably an array of photoelectronic transducers arranged transversely of the passing fibrous array. If the means for analysing the signals therefrom is adapted to cause the composite sensor to scan the fibrous array, the size of any defect can readily be determined.

The invention will be further described, by way of example only, with reference to the drawings in which:—

Fig. 1 is a diagrammatic representation of the drafting and video system of one form of apparatus embodying the invention;

Fig. 2 is a detailed diagram of a transparency sensor system employed in Fig. 1;

Fig. 3 is a detailed diagram of a reflectance sensor system employed in Fig. 1.

Fig. 4 is a block diagram of an interface system interconnecting the video system of Fig. 1 and an analysing computer; and

Fig. 5 is a further block diagram illustrating certain functions of the apparatus of Figs. 1 to 4.

Fig. 6 is a diagram showing the detection levels for the video signal; and

Fig. 7 is a flowchart illustrating criteria for defect classification.

The preferred system of this invention is based on an optical analysis of the image of the top or other array of fibres projected on a set of two linear photodiode arrays. This type of sensor includes, integrated in the same substrate, for instance 1024 photodiodes which are about 25 micrometers apart from each other and form a 15 to 36 micrometer band. A set of linear CCD (charge-coupled devices) sensors, or a CCD matrix, can also be used.

The top is illuminated in two different ways. In the first, the light source is so placed that light passes through the top.

This is illustrated in Fig. 2, in which the 'transparency sensor' 11 with its associated optical system 12 is arranged over the top or other fibrous array 13 and a tubular light source 14 is arranged beneath the array.

Both optical system 12 and 22 form an image of a transversal line of the fibre array on the sensors.

In the second way, the light source is so placed that light is reflected by the top.

This is illustrated in Fig. 3, in which the 'reflection sensor' 21 and associated optical system 22 is arranged over the top 13, while two symmetrically placed tubular light sources 24 above the top cooperate with a reflecting background or diffusing screen 25 below the top.

In the drafting and video system shown in Fig. 1, the top 13 is supplied from a drafting system comprising a double apron 26 and front rollers 27 and is drawn past the sensors 11 and 21 by a further pair of rollers 28. The transparency sensor 11 is located near the reflection sensor 21 at a fixed distance and both sensors periodically scan the top 13 at right angles to its direction of movement and parallel to its surface at the end of the drafting machine (7, 28). The two sensors and their respective light sources are separated by an intervening dark panel 29 provided with a slit through which the top passes.

By means of an appropriate circuit, a train of 1024 pulses is obtained from each sensor, the amplitude of each pulse being proportional to the light falling on the respective photodiode. The train of pulses forms a video signal. The video signals are converted into a string of 16-bit words and buffered in a FIFO (first-in first-out) memory before transmission to a host computer. The electronic circuitry required to convert the video signals to a 16-bit word is contained in an interface system shown in detail in Fig. 4 and described hereinafter. The interface system is under the control of a microprocessor which unloads the FIFO's and transmits the information to the host computer through serial lines.

The host computer calculates parameters of the detected defects, classifies the defects and prints-out a résumé at the end of the analysis.

The individual units of a preferred apparatus

according to the invention and their manner of operation will now be described in greater detail.

Drafting unit

The drafting unit is shown diagrammatically in Fig. 1 and is required to prepare the fibrous material for the analysis. The materials should preferably be drafted to approximately 1 g/m (1 tex) with a maximum width of 128 mm.

In drafting the material, an apron 26 is used to reduce the number of adjustment necessary with the various type of material to be analysed. In the zone under the sensors the material should remain horizontal and drafted, and must pass at constant speed.

Information about the speed and movement of the top is transmitted to the interface system.

Video unit

The video unit shown in Fig. 1 incorporates the support for the top, the light sources 14, 24 for its illumination, the optics 12, 22 and accessories for projection on the linear photodiode arrays, the photodiode array sensors 11, 21 themselves and the control circuits therefor, which are contained in a front end unit 31.

The top passes at a constant speed horizontally beneath the sensors and crosses an area that is uniformly illuminated by incandescent lamps of the tubular type. By means of the optical system, an image is projected on the respective sensor. The luminous image generates a proportional voltage in each photodiode, which is extracted in the form of a train of pulses by an appropriate electronic circuit.

Illumination of the light sources may be controlled by the interface system, and is powered by DC regulated voltage. Movement of the top and the scanning pulses used for the CCD are synchronised.

The main purpose of the transparency sensor 11 is to determine the actual size of a defect.

The top is drafted in such a way that it is invisible to the transparency sensor and the video signal is normally a constant corresponding to the intensity of illumination for the tubular light source projected on the CCD.

The purpose of the reflection sensor 21 is to discriminate defects on a basis of brightness characteristics. The analysis must be performed not too far from the transparency sensor to avoid movement of the defect in the top.

The reflection sensor receives light from two sources: light reflected from the drafted sliver and light reflected from the background diffusing reflector (or emitted by the background opalescent material covering an auxiliary light source). The diffusing reflector is made of a material matching the colour and reflectance of the wool fibres, so that the fibre web disappears against this background.

In the absence of any defect, the illumination level of the light source is adjusted so that the signal issued from the photodiodes is about half way between the dark and the saturation levels. The signals issued from each of the 1024 photodiodes are roughly identical, xcept for variations due to small differences of sensitivity between individual photodiodes and of a systematic variation in light intensity between centre and sides, due to the difference in distance from the source. This systematic difference being compensated in the electronic amplifier system, an approximately constant video signal, appearing as a horizontal line at 50% between dark level (0%) and saturation (100%), is obtained if observed on the screen of an oscillograph. If a fibrous defect (for instance a nep, formed by an entanglement of fibres with a compact core) appears, an increase of the amount of reflected light over the background level is detected at this point, and a corresponding increase of the video signal from 50 to say 75% is observed. If a vegetable defect (grass, burr or piece of burr, etc.) appears in the drafted sliver, a decrease in the amount of reflected light at this point is observed, and the video signal shows a decrease from 50 to say 25%. It is thus possible by this method to discriminate between fibrous and vegetable defects.

This is because the white fibrous defect is both very bright, and on the other hand semi-opaque, which allows a part of the light reflected from the background diffusing reflector to be transmitted through the fibrous defect. On the contrary, a yellow or brown vegetable defect is both less bright than the surrounding web of fibres, and nearly completely opaque, and thus transmits only a very small part of the light reflected from the background diffusing reflector. The two effects contribute in this case to a reduction of the light intensity received by the reflection sensor. The video signal from the transmission sensor is used mainly for the determination of the form and size of the defect, but also for a partial identification of the defects (fibrous or vegetable) based on the level of reduction of transmitted light (corresponding to opacity) and on the slope of this reduction at the edge of the defect. For this purpose, 5 detection levels TH1 to TH5 are set to evaluate the opacity of each defect (Fig. 6). For a fibrous defect, a nep for instance, the opacity will be medium (for instance reaching only level 3 in the core) and the slope from the level 1 crossing to the level 3 crossing relatively low. For a vegetable defect, the opacity will be higher (level 4 or 5 exceeded), and the slope high, because the edges of the defect are sharper for light transmission. However, the tests by the computer on these two criteria are not sufficient to ensure a correct identification in all cases between fibrous and vegetable defects. The additional criteria increase or decrease of the video signal given by the reflection sensor, is used to confirm the identification in borderline cases. A software program giving a weight factor for each criterion makes the final classification.

The determination of the size of the defects is better made on the transmission signal, because the contrast and the "signal to noise" or "signal to

background" ratio are much better than on the reflection signal. On the latter, the small neps and the low density fibrous defects disappear completely and the transition on the edges of the other defects are fuzzy and not well defined.

As mentioned above, the transmission sensor receives an image of greater clarity and thus an accurate indication of the present, size and shape of the defect. The reflection sensor permits identification of vegetable defects as such; since these have a lower reflectivity. Fibrous defects can be recognised by their higher reflectivity, although this is not such a marked change as in the case of vegetable defects. Alternatively, defects identified and not indicated by the reflection sensor as being vegetable may then be assumed to be fibrous. Vegetable defects not identified by the reflection sensor for any reason may nevertheless be identified owing to their shape or from the slope of the video signal.

Further classification as to type of defect may be made on the basis of the signals from the transmission sensor, the shape of the defect indicating a particular type of vegetable defect.

An example of the software analysis of the video signal is given in Fig. 7.

The ratio R/T of the signal R (taking the 50% grey level as a reference) to the transmitted signal T (taking the saturation level 100% as a reference) makes the distinction between fibrous and vegetable defects. Indeed, for a vegetable defect, the affected R signal will be large and negative (towards the dark level) and the transmitted signal T large and negative (towards the dark level). The ratio will thus be positive and close to 1.

For a fibrous defect, R will be positive and small T, will be negative and large. The ratio will thus be negative and small, close to 0 in most cases.

Other classes of defects are identified on the base of the shape, the grey level and the projected 'length' L_p.

Interface system

The interface system as shown in Fig. 4 may be divided into the following items:—

signal processing 32 and FIFO memory 33, each one associated with a particular sensor; microprocessor 34 with RAM 35 and a specialised program; transmission channels to the host computer 36 via serial lines 37; and counters and control logics.

The video signal from the photodiode array is amplified in a differential amplifier 41 and is used to generate an automatic video reference signal 42 which reflect the mean value of every photodiode when the top has no defect. Subtraction in the amplifier 43 of the video reference signal from the video signal gives at the input of the comparator and threshold logic 44 a peak which represents only the detected defect. This signal is then compared with threshold levels and the amplitude is digitised.

The reference signal may be used to provide automatic brightness control for the light source. Moreover, provision may also be made for automatic adjustment of the threshold level in response to changing circumstances.

To reduce the volume of information transmitted to the host computer, the defect which is under scanning is résuméd in a string of 16-bit words, each word informing the host computer of the following information:—

10 bits for the photodiode numbers: X=0 to 1023

3 bits for the threshold level which was crossed and flags

1 bit to identify 'X type information'

During the scanning, when a defect is detected, the digital integrator 45 computes the volume of darkness Σ represented by the defect and this information is transmitted with a special flag as an X type word, just after the end of the detected defect.

At the end of the scanned line, is a defect was detected and X and Σ information was loaded, the Y information is added.

The Y information is also a 16-bit word with the following information.

12 bits for the line scanning number

1 bit to identify 'Y type of information'

3 bits for flags such as end of analysis

An item of Y information must be followed by a string of X information concerning the same scanned line. The Y information may be alone to transmit the information contained by the flags. The line number is transmitted only when a defect has appeared in the line. The END flag is transmitted upon reception of a microprocessor command which tells the host computer that it was the last information.

Host computer

The host computer is used to calculate a set of parameters for each defect using data from every sensor.

To increase the speed of the process, the computer will never have in memory the complete image of the defect, but only certain arrays which are completed by the received information. The end of the defect is recognised by the computer by the presence of the GAP flag in a 'Y type of information'.

At this moment, the computer will 'superpose' the arrays of each sensor to have information from all the sensors on the same defect and will compute and compare a set of parameters to determine the characteristics of the defect, which can be classified according to specified rules. When the END flag is detected, the host computer will print-out a résumé of the classification.

The classification may be required to compute such parameters as size, shape, grey levels, projected length, discontinuities, and ratio between sensors for the above parameters.

Results

The sensors may scan the top at a rate and sensitivity such that a photodiode will 'see'

contiguous squares of 1/8 mm on a 128 mm wide top. The speed of the top under the sensors may be more than 1.5 m/min.

When a FIFO full condition occurs, the information already processed is not lost but a résumé is done automatically.

The top may be passed under the sensors without analysis, this is helpful to prepare the top correctly before starting the analysis.

The résumé may be transmitted to another computer for data storage. The résumé may give information on defects per meter and per unit weight of analysed top.

Although in this specification and in the claims which follow, reference has been made to 'light', it will be apparent that forms of electromagnetic radiation other than the visible spectrum may be employed for the purposes of the invention, in association with appropriate sensors, and the term 'light' should be construed accordingly throughout.

Claims

1. A method of detecting defects in an array of fibres, which comprises passing the array past at least two light-responsive sensors, directing light onto the array, one sensor being arranged to respond to light transmitted through the array and another being arranged to respond to light reflected from the array, the signals produced by the first sensor being synchronized with those produced by the second sensor in respect of the same portion of the array, and detecting the presence or character of a defect from signals produced by the sensor during passage of a defect thereby.

2. A method according to claim 1 in which the signals are analysed to detect the presence or size of a defect.

3. A method according to claim 2 in which an automatic reference signal is generated which represents the mean value of the said signals in the absence of a defect, and the reference signal is subtracted from the incoming signals from the sensors to reveal a defect as a peak in the difference.

4. A method according to claim 2 or 3 in which the sensor comprises a transversely oriented array of photoelectric transducers which are used to scan the passing array, and in which the output of the transducers is supplied to a computer which produces an output indicating the presence or size of any defect.

5. A method according to any of claims 1 to 4 in which the signals are analysed to determine the character of a defect.

6. A method according to claim 5, in which the fibrous array is illuminated from the same side as and from the opposite side to the sensor and the signals produced by the sensor are analysed with respect to the transmittance and reflectance of the array.

7. A method according to claim 6 in which the relative intensity of the illumination from the same and from the opposite side is adjusted to a value at which the intensity detected by the sensor in the presence of the fibrous array and in the absence of a defect equals the intensity of illumination from the opposite side detected in the absence of the array.

8. A method according to claim 6 or 7, in which the illumination from one side of the fibrous array is provided by reflection of light passing through the array from a light source on the other side.

9. Apparatus for detecting defects in an array of fibres, comprising means for conveying a fibrous array, a source of light directed towards the array and so disposed in relation to the sensor that light transmitted or reflected by the array falls respectively on first and second sensors, and means to analyse signals produced by the sensors in response to the light falling upon them.

10. Apparatus according to claim 9, in which two sensors are spaced apart alongside the path of the fibrous array, a source of light is disposed on the opposite side of the said path to one of the sensors and second and third sources of light are disposed respectively on the same and the opposite sides of the array as the other sensor.

11. Apparatus according to claim 10, in which the third source of light is a reflector disposed to reflect light from the second source towards the said other sensor.

12. Apparatus according to claim 9, 10 or 11, in which the or each sensor comprises a transversely oriented array of photoelectric transducers, and the analysing means is adapted to cause each array of transducers to scan a fibrous array as it passes such sensor.

13. Apparatus according to any of claims 9 to 12 in which the analysing means comprises a computer adapted to produce from the output of the sensor or sensors signals indicative of the presence, size or character of any defect.

14. Apparatus according to any of claims 9 to 13, in which the conveying means includes a drafting system.

15. Apparatus for detecting defects in an array of fibres, substantially as hereinbefore described with reference to the accompanying drawings.

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